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Inlet device with double exponential profile for spatial distribution of air in ventilated areas

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Abstract

Amendments changes to the nature of human activities, which tends more towards a seated type activity, requires reconsideration of the design and the execution of ventilation and air conditioning equipment. Under these conditions, the comfort air velocity must have lower values, which implies special distribution measures to achieve a strictly controlled indoor air movement. The chosen solution for ensuring a flow of the inlet air jet as close as possible to the theoretical model, is based on a double exponential discharge device distributor. In the Laboratory of Ventilation and Air Conditioning of the Technical University of Cluj-Napoca, was designed and built an experimental stand (see Figure 1 and Figure 3) in order to investigate the velocity field of a double-equal strength (double exponential profile) inlet device for spatial air-distribution

Rezumat

Schimbările înregistrate în modificarea naturii activităţii umane, care tinde tot mai mult spre o activitate de tip aşezat, impune reconsiderarea modului de concepere şi realizare a instalaţiilor de ventilare-climatizare. În aceste condiţii, viteza de confort a aerului primeşte valori tot mai reduse, situaţie ce impune măsuri speciale pentru realizarea unei distribuţii interioare a aerului controlate riguros. Soluţia preconizată pentru asigurarea unei curgeri a jetului cât mai apropiată de cea teoretică se bazează pe un profil dublu exponenţial al distribuitorului dispozitivului de refulare. În Laboratorul de Instalaţii de Ventilare şi Condiţionaredin cadrula Universităţii Tehnice din Cluj-Napoca s-a conceput şi realizat un stand (vezi Figura 1 şi Figura 3) pentru investigarea câmpului de viteze al unui dispozitiv de introducere-distribuţie spaţială a aerului de dublă egală rezistenţă (cu profil dublu exponenţial).

Keywords: ventilation, inlet, air flow, distribution, movement, exponential, device.

1. Introduction

The main purpose of the inlet devices is to achieve ventilation effect by obtaining a proper distribution of the introduced air jet. Therefore, is necessary to use inlet devices that allow the introduction of a maximum rate of air into a room without exceeding admissible indoor air velocities in the occupied zone [1].
This paper presents a device for introducing air with the novelty of double-exponential profile of

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the distributor. This allows entering the rooms of large quantities of blow-in air with low velocities, with the result of possible use in locations with a high required air exchange.
Since the air distribution in mechanically ventilated rooms is determined for the most part (about 90%) of air jets, it means that the current lines generated by air jets must provide appropriate ventilation effect primarily in the occupied zone [1]. A number of clean rooms ventilation solutions (e.g. operating theaters) recommended the use of large inlet air devices to enable the introduction of high rates of airflow with low primary air velocities values [2]. In this way it increases also the phenomenon of indoor air induction into the main stream of the inlet air jet.
In real situations, the current lines of the air jets are more or less influenced by other fields of air pressure created in natural or mechanical way by infiltrated or accidentally appeared air currents, by the presence of natural obstacles which are due to the presence of machinery, furniture, building components or the occupants themselves. Compare with this, both in theoretical studies and researches on experimental stands, it creates the conditions for free airflow evolution. It is considered that the air jet current lines are arising from the pole of the jet. Also, it must be taken measures to stabilize the airflow in the ventilation duct in the upstream section from the inlet device.

2. Experimental stand and measurement apparatus

The solution presented in this paper refers to a double exponential discharge device distributor, in order to ensure a flow of the inlet air jet as close as possible to the theoretical model of free isothermal jet [1].
For this purpose, in the Laboratory of Ventilation and Air Conditioning of the Technical University of Cluj-Napoca, is designed and built an experimental stand (see Figure 1 and Figure 2) for the measurement of the air velocity field of a double-equal strength (double exponential profile) inlet device for spatial air-distribution.

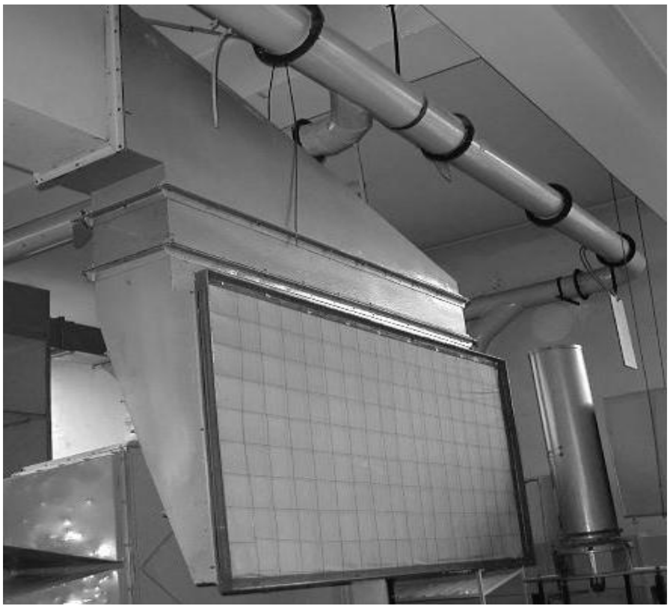

Figure 1. Stand for studying the air velocity field of the double-equal strength inlet device (double-exponential profile) for spatial air-distribution.

The airflow measurement apparatus is a digital thermo-anemometer (TA 35 type AIRFLOW) with high accuracy class (±0.01 m/s) and measurement range for air velocity from 0.05 m/s to 25 m/s.

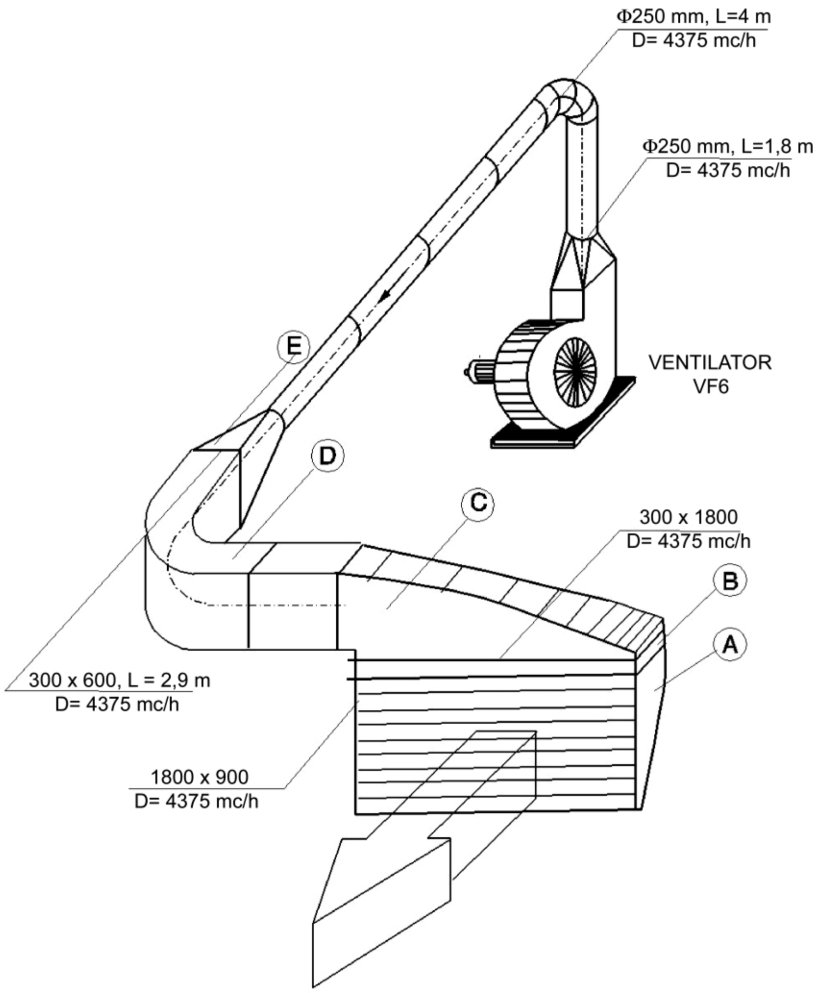

Figure 2. Stand for studying the air velocity field of the double-equal strength inlet device (double-exponential profile)– Isometric drawing.

The stand is made of the following components (see Figure 2):

- A – simple-equal strength (simple exponential profile) inlet device, size: 900 x 1800 mm, fitted with adjustable blades to produce a uniform air distribution throughout the discharge plane;
- B – rectangular connecting duct with internal airflow stabilization blades, size: 300 x 1800 mm, to achieve a plane-parallel airflow;
- C - distributor of simple-equal strength of the inlet device, size: 300 x 1800 mm, to assure stationary plane-parallel airflow in the upstream section;
- D –rectangular bend (90º) with internal airflow stabilization blades;
- E - reducer from rectangular to circular section;
- V - mono-aspirant centrifugal fan with airflow rate D = 4375 m^3/h.

The whole inlet device is made of three main components: A, B and C.

The double-equal strength (double exponential profile) inlet device for spatial air-distribution was designed by applying twice (for horizontal and for vertical distribution) the equations which allow to calculate the dimensions of the two distributors with variable section [3], represented in Figure 2 by parts A and C.

All inlet devices intend to supply air in the occupied area at values for velocity, temperature, humidity, concentrations of different pollutants that correspond to the comfort conditions in the

room. These considerations lead to the value of the initial velocity in the discharge plane, noted with v_0. To ensure the uniformity of ventilation, the air velocity is advisable to be as close to a constant value all over the discharge plane.
In this way, the initial velocity v_0 in the discharge plan of the device will be constantly around 0,75 m/s, a value which corresponds to an easy physical activity. Due to the large size of the inlet device, it was necessary to provide airflow stabilization and control blades.
The air jet develops into a free space, which is not influenced by any disturbance surfaces or objects, so the measurements will not be at all affected.

3. Measurements and processing results

The investigation of the air velocity field of the double-equal strength inlet device (double-exponential profile) involves measuring the values of air velocity with an apparatus that does not influence the course of the current lines through both specialized transducer dimensions and the manner of making measurements [4].
We performed a sufficient number of measurements, with enough equipment accuracy, to provide accurate values of air velocity into the air jet streams [4].

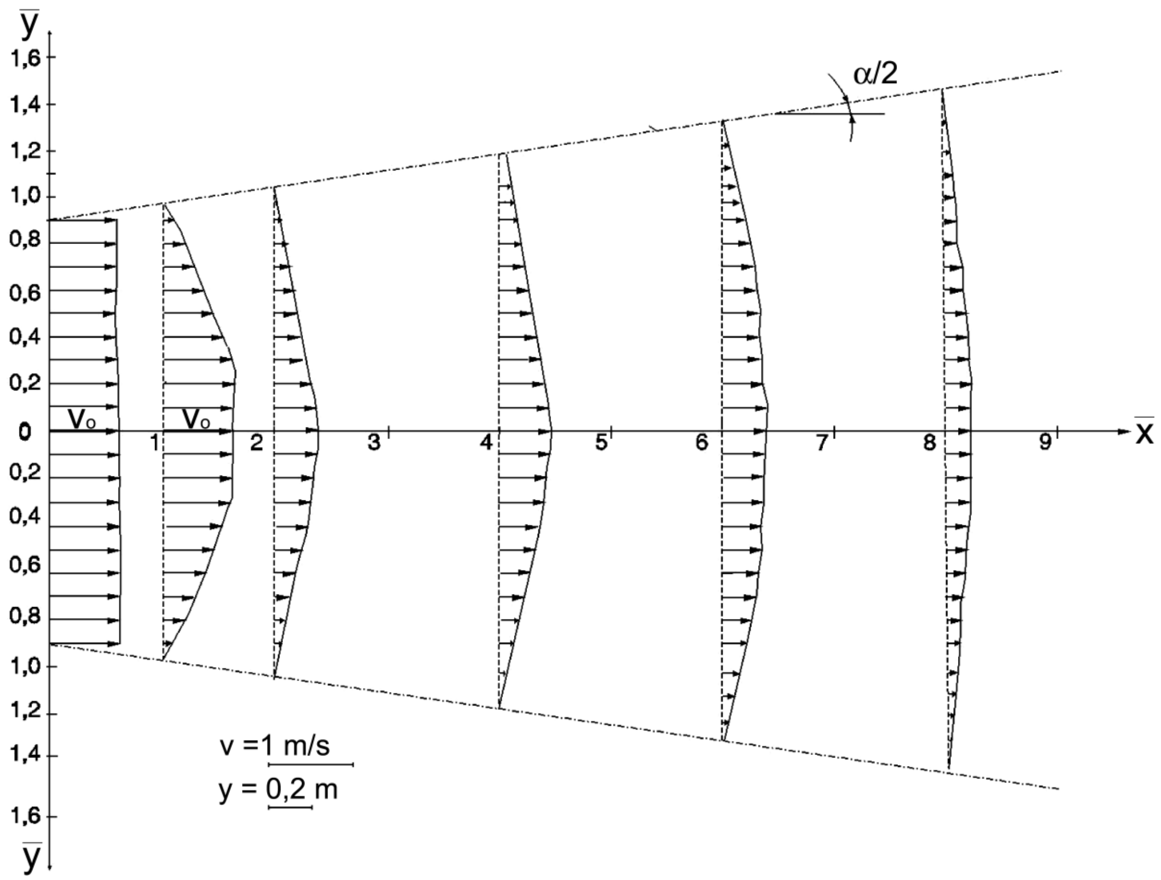

Figure 3. Air velocity hodographs measured in horizontal plane.

To measure the air velocities along the jet, in perpendicular planes to the jet axis, at different distances (noted with x) from the discharge plane, is using a classical method that uses, for keeping the same measurement points along the jet, a roller grid with square mesh [4]. Measuring transverse planes of the air velocity field have been predetermined by aforementioned rectangular roller grid with dimensions of 3000 x 1500 mm and with 100 x 100 mm square mesh. The measuring grid was placed successively at predetermined distances from the plane of discharge, beginning with the distance x = 0 m (discharge plane) and finishing at the distance where axial air velocity is 0.25 m/s. Measured velocities were noted in all the nodes of the grid [4], resulting the air velocity hodographs in two perpendicular planes: one, horizontal and the other one, vertical (see Figure 3 and Figure 4) [2], [4].

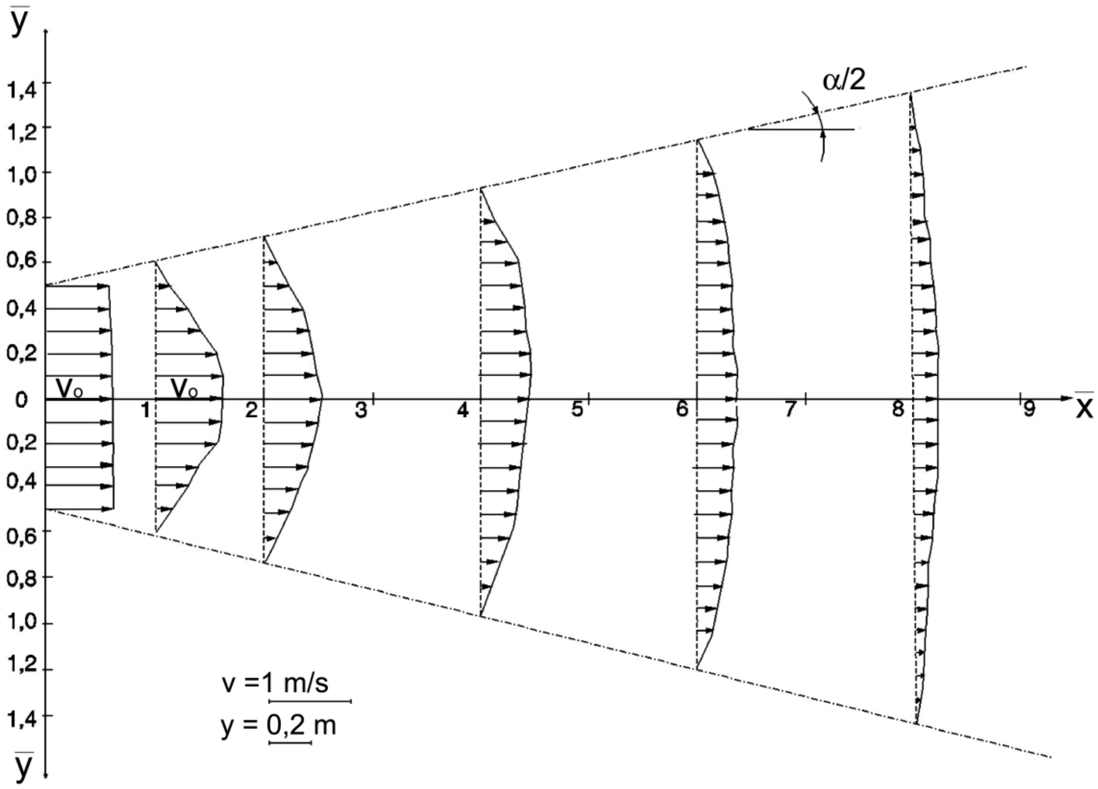

Figure 4. Air velocity hodographs measured in vertical plane.

In preparation for developing the mathematical model of the spatial air jet, it was chosen the dimensionless mode of expression of geometric and kinematic quantities. Thus, the measurements were made at dimensionless distances: $\bar{x} = 0$, $\bar{x} = 1$, $\bar{x} = 2$, $\bar{x} = 4$, $\bar{x} = 6$ and $\bar{x} = 8$, resulting the hodographs of air velocities in two perpendicular planes (see Figure 3 and Figure 4). The expression of dimensionless distances is: $\bar{x} = \frac{x}{d_o}$ ($d_o = \frac{2 \cdot a \cdot b}{a + b}$ – equivalent diameter of the rectangular inlet device with dimensions a and b).

After the air comes out the discharge device, enter into a stagnant air environment. As the air jet moving mass advances, due to induction, an amount of increasingly higher of stagnant air join to the moving air. In this way, the initial air jet kinetic energy is gradually consumed, decreasing the speed of air movement.

The hodographs of air velocities has changed from rectangle (in the discharge plane) to curvilinear trapezoid, respectively curvilinear triangle with the growth of distance [2]. The configuration of the isokinetic curves highlights the shape of the air jet. This represents a greater approach to the free, round, isotherm air jet [1]. This is also explained by the ratio 1:2 between the sides of the discharge device.

Based on the measured air velocities in the grid nodes, isokinetic curves were drawn (see Figure 5, Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10).

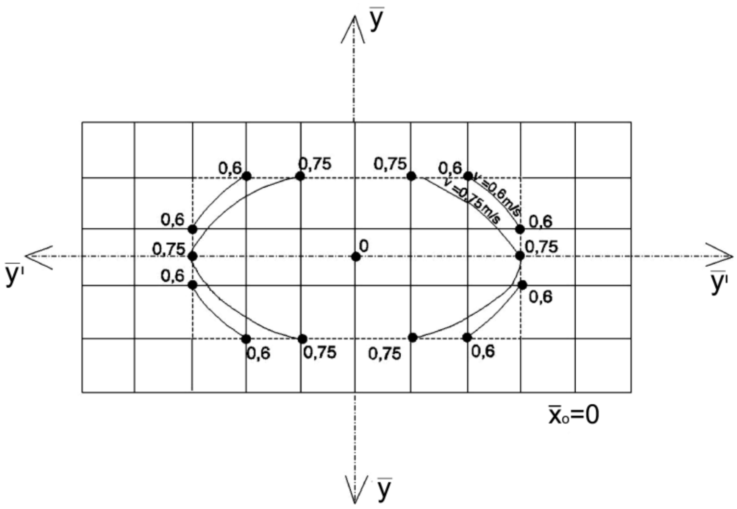

Figure 5. Isokinetic curves for $\overline{x}$ = 0.

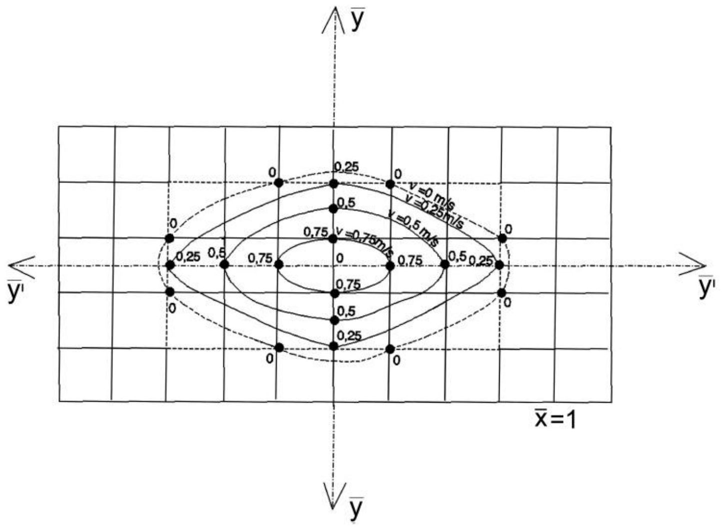

Figure 6. Isokinetic curves for $\overline{x}$ = 1.

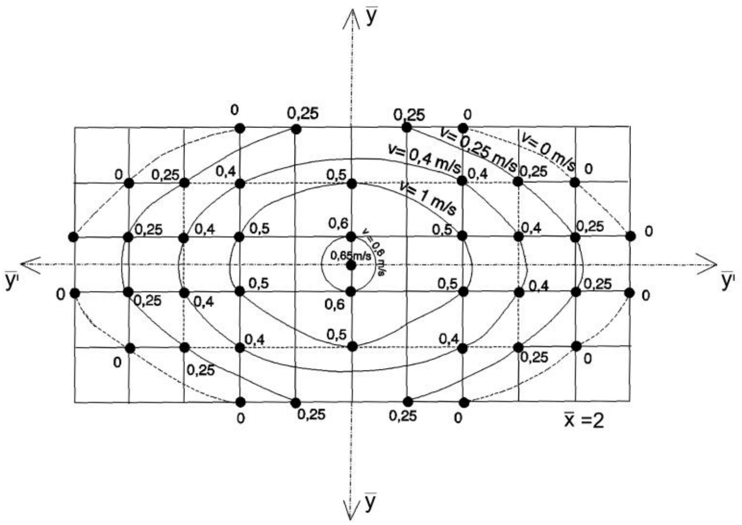

Figure 7. Isokinetic curves for $\overline{x}$ = 2.

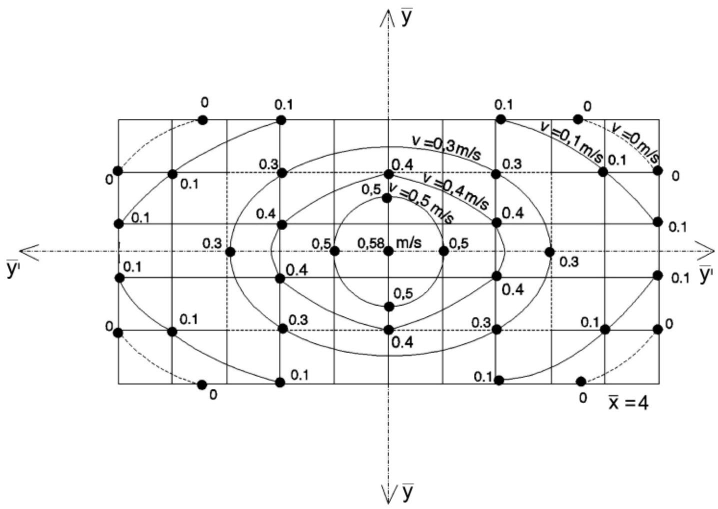

Figure 8. Isokinetic curves for $\overline{x}$ = 4.

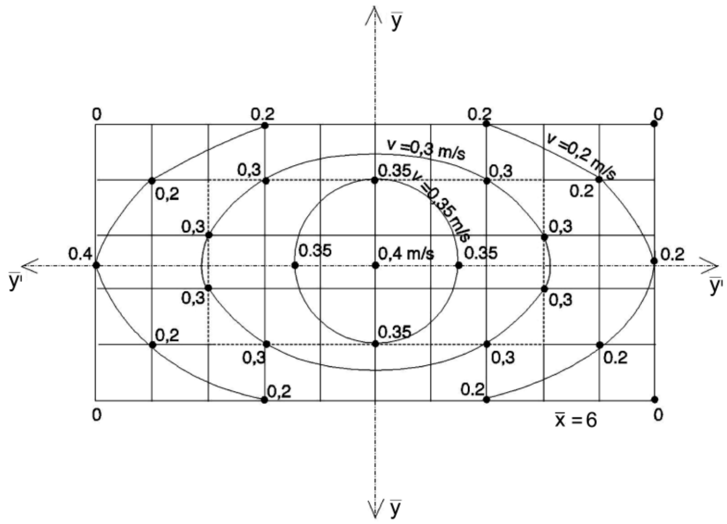

Figure 9. Isokinetic curves for $\overline{x}$ = 6.

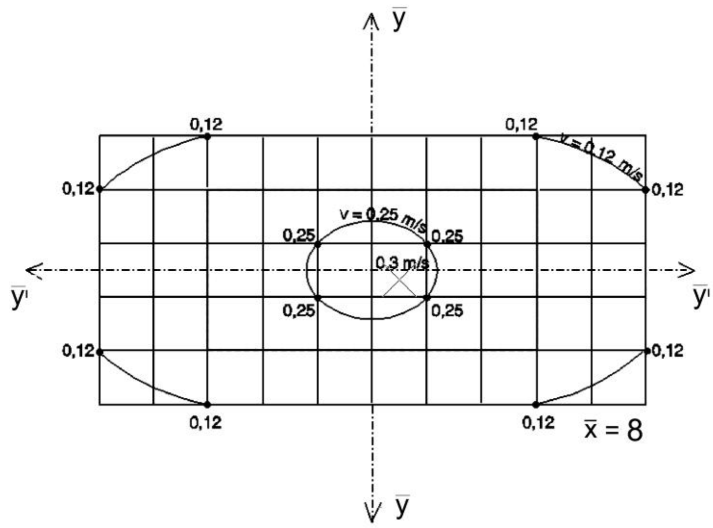

Figure 10. Isokinetic curves for $\overline{x}$ = 8.

The air velocities hodographs form revealed the air jet envelope and angle of divergence, which depends on the initial airflow rate. The result is a divergence angle of the air jet α of about 32° and a dimensionless air jet throw equal with 9.
These curves also highlighted the three areas of this type of air jet, with the following lengths:

- initial sector $X_1 = 1.4 \times d_0$;
- transition sector $X_2 = 1.2 \times d_0$;
- main sector $X_3 = 6.4 \times d_0$.

The air velocity hodographs confirmed the increase of airflow rate in the air jet with the distance to the discharge plane.
Accepting the theory of similarity, the measurements that were made will allow establishing a mathematical model of these air supply system through a large inlet area [5].
In this order, we will apply the classical method of calculation the jets characteristic elements that use the dividing the variable elements along the jet to the constant elements from the device discharge plan, resulting dimensionless variables [1]. The results will be presented as dimensionless variables in order to ensure that this can be generalized and easily applied to other values of airflow rates or other dimensions of inlet devices.

4. Conclusions

This type of air jet presents a compact enlargement with a divergence angle of 32°, a dimensionless air jet throw equal with 9 and an induction factor appropriate for a satisfactory ventilation effect.
The double-equal strength inlet device (double-exponential profile) provides relatively uniform air velocities in any perpendicular measurement planes of the air jet stream. Thus, the proposed solution can be used to provide ventilated air in many applications. Also, the large range obtained for air velocities lead to a great flexibility in operations for this kind of devices.
Following the evolutionary stage of inlet air devices, able to achieve enhanced ventilation effects, the designed and executed stand has the some advantages:

- Provides a controlled airflow, close to laminar airflow conditions;
- Provides to the ventilated room an approximately constant air quality, appropriate for indoor environment demanded comfort;
- Ensures investment, execution and exploitation costs at reasonable values;
- Assures a good opportunity of harmonization with interior design elements;
- Provides the possibility of directing the air jet, where it requires, towards certain areas that require greater conditioned air airflow.

5. References

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